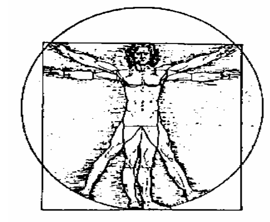

Habitat 2004

Enhanced Lighting Techniques and Augmented Reality To Improve Human Task Performance

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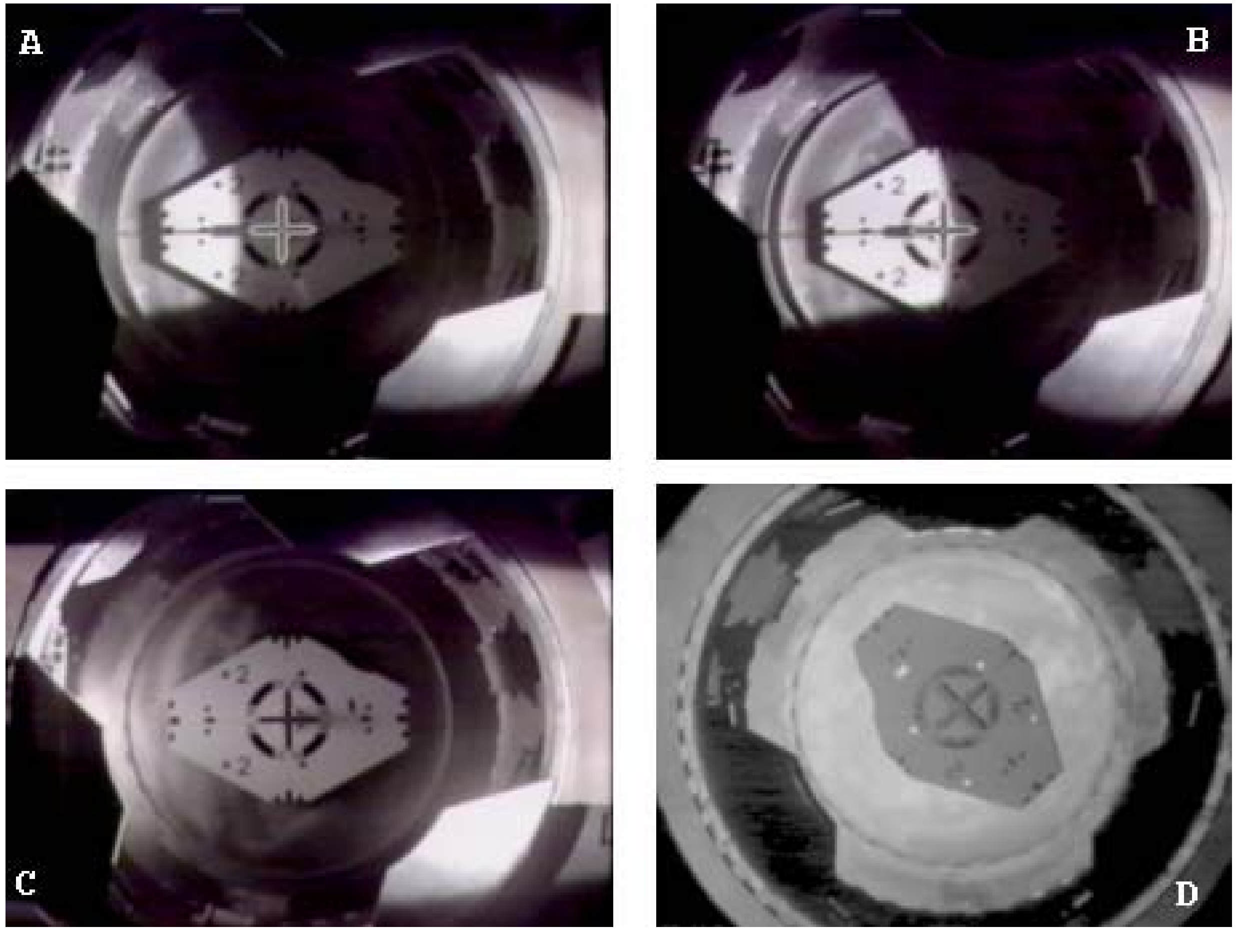
Abstract

"On orbit" tasks involve procedures that are very complex and highly dependent on the availability of visual information. In many situations, cameras are used as tools to help overcome the visual and physical restrictions associated with space flight. However, these cameras are affected by the dynamic lighting conditions of space, particularly during critical robotic and EMU operations. Normal training for these tasks includes computer generated simulations of planned camera views. Improvement of current trainer design using enhanced visual display information (dynamic overlays or augmented reality) and the use of shadowing in computer-aided training (a major enhancement to current simulators) are candidates for improving human performance. Because of the potentially significant costs of implementation in production trainers, it is important to accurately determine the degree of improvement.

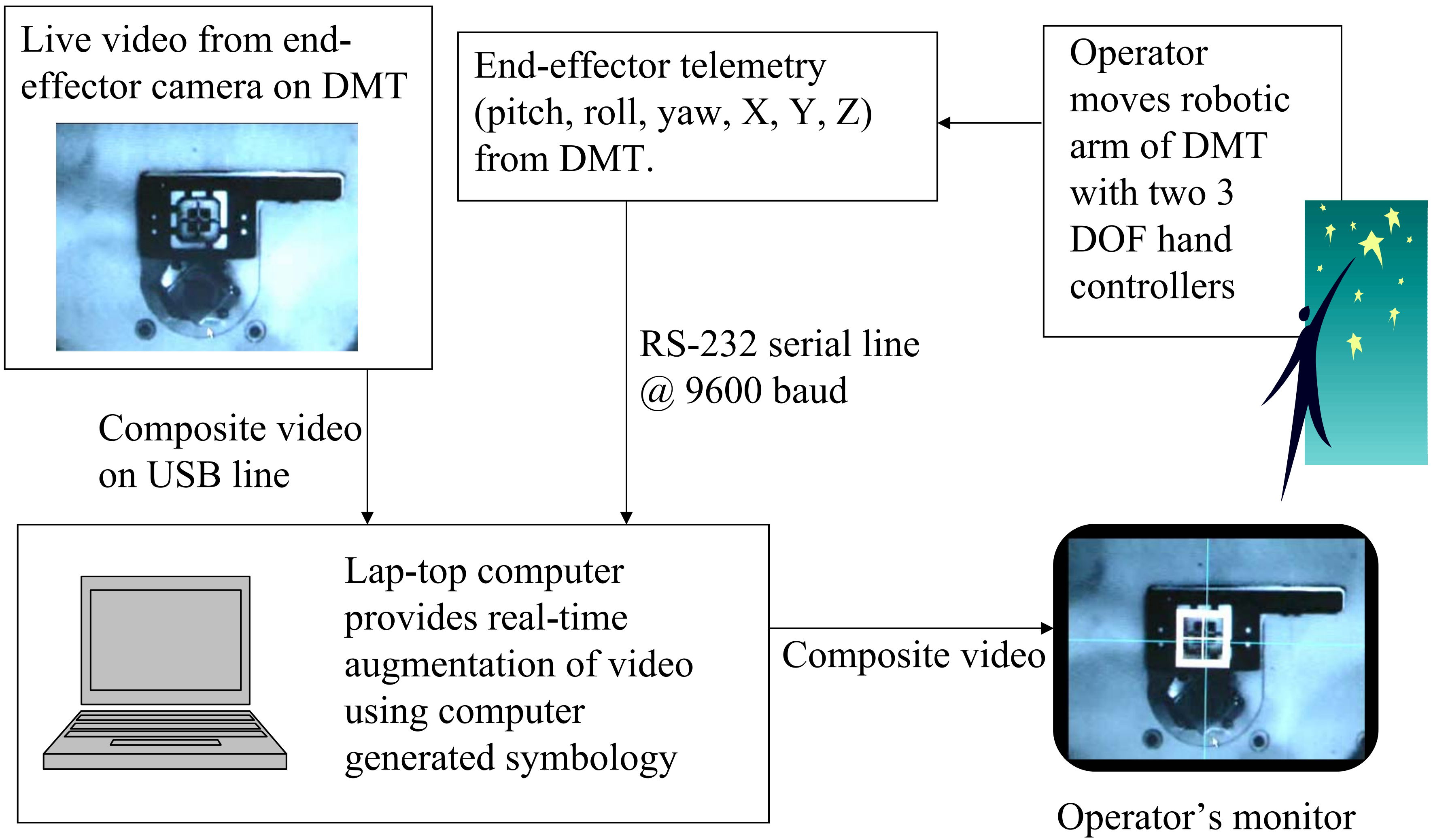
Abstract (continued)



Example: Typical On-Orbit Lighting Conditions for a Docking Target

Abstract (continued)

In the case of dynamic overlays or augmented reality, the proposed project will perform subject testing in the Multiuse Remote Manipulator Development Facility at Johnson Space Center (MRMDF). The project will investigate the use of augmented reality to assist payload berthing where alignment guides are structural elements not necessarily dedicated or known in advance as alignment cues. Current efforts in the MRMDF are focusing on improving grappling operations using augmented reality technology. Using the AR Toolkit from the University of Washington, graphical images and alignment guides are overlaid on live video. The system has been ported to a laptop and uses a USB port for video input. Initial testing is being done in the in the MRMDF on the Dexterous Manipulator Trainer.



DMT Augmented Reality System Flow Chart.

What is Augmented or Enhanced Reality ? It is a variation of Virtual Reality (VR). VR technology completely immerses the user inside a synthetic environment. While immersed, the user cannot see the real world around him.

In contrast, AR allows the user to see the real world, with virtual objects or graphics, audio and other sense enhancements superimposed over a real-world environment in real-time.

P. Milgram's Reality-Virtuality Continuum

Why is combining real and virtual objects in 3-D useful?

Augmented Reality enhances a user's perception and interaction with the real world. The virtual objects display information that the user cannot directly detect with his own senses. The information conveyed by the virtual objects helps a user perform real-world tasks.

Extensive use of AR in Sports

AR is already used in sports broadcasting. The annotations on the race cars and the yellow first down line are inserted as overlays into the broadcast in real time.

(Courtesy of NASCAR and Sportvision)

Why Is Augmented Reality an Interesting Topic?

Consider what AR could make routinely possible.

a) A repair-person viewing a broken piece of equipment could see instructions highlighting the parts that need to be inspected.

b) Firefighters could see the layout of a burning building, allowing them to avoid hazards that would otherwise be invisible.

c) A tourist could glance down a street and see a review of each restaurant on the block.

Other Potential AR applications:

- Medical
    - visualization during surgical operations
- Annotations for maintenance and repair operations
    - assembly, maintenance, and repair of complex machinery
- Robotic systems operations
    - Path planning
- Military aircraft operations
    - navigation, weapons targeting

Issues for AR

Registration

The registration of the synthetic, virtual world with the live image needs to be dynamic and accurate. This is the most difficult problem to solve for AR. There are currently two techniques which are commonly used.

• Camera registration. The location and attitude of the eye point is known relative to a known environment.

• Image registration. Compute the location of the eye point using object recognition by image processing.

Issues for AR (cont'd)

View management

Determination of the correct amount and type of information to mix with the live image. Human perception issues are also involved. This is a rich field of options.

- Geometry – 3D models of the objects in the scene, 3D outlines and guidelines, predicted paths of motion, etc.

- Annotation – text information

AR in Space

There are some unique aspects to space flight with regard to AR.

We have virtual representations of most of the objects we put in space and we know where most of them are located.

We know where most of the cameras are located and potentially know where they are pointed.

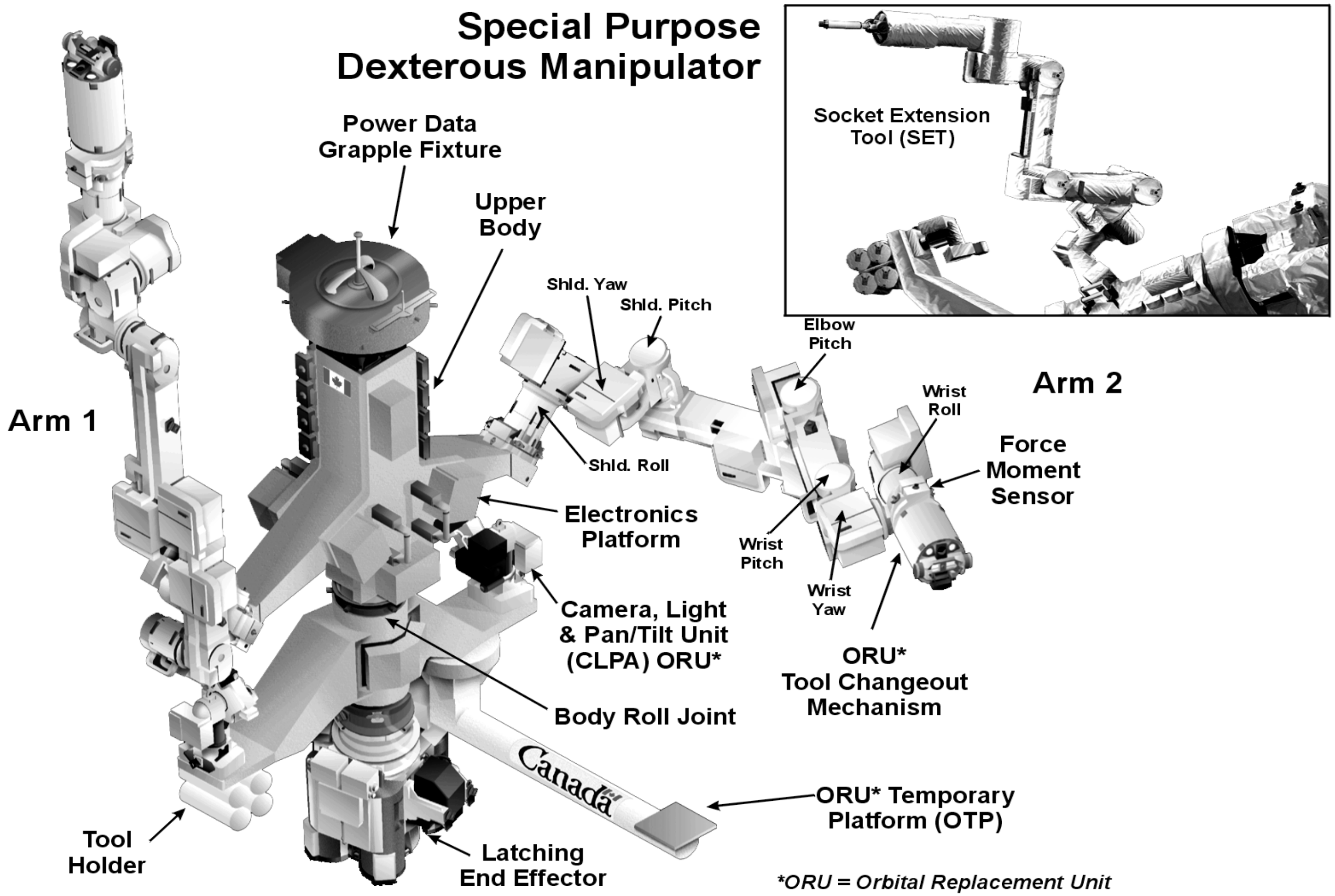
Because of the dynamic nature of illumination in space, the the camera registration technique is the strongest (less dependent on illumination than image registration), but a hybrid system would be ideal.

Where Will We Apply the AR Technology at NASA? What Benefits Can It Bring?

AR Technology is planned to be applied on SPDM (special purpose dexterous manipulator). The Dextrous Manipulator Trainer (DMT) is the ground-based version of the SPDM.

SPDM is used to assist the Canadian robotic arm with its robotic tasks in the International Space Station and assist astronauts with their robotic tasks.

This technology on the SPDM has the potential to reduce the amount of time to perform a certain robotic task increase accuracy and visibility as graphical overlay will provide extra information and accurate location of the target.

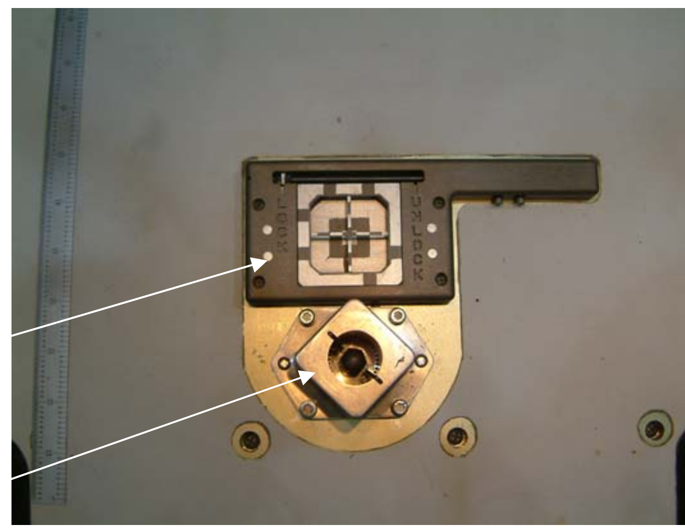


Special Purpose Dexterous Manipulator (SPDM)

Dexterous Manipulator Trainer (DMT) is a ground-based mockup of SPDM.

Single arm of DMT being positioned over a grapple fixture by an operator

End-effector camera view of a grapple fixture under ideal lighting conditions



Alignment Guide

Grapple Fixture

Experimental Design

Four test scenarios will be constructed such that they are unique but are of equal difficulty. Each test scenario will always be associated with one of the four test conditions. In addition, a fifth scenario will be developed for a practice trial. A repeated measures design is preferred for this study because of the low number of certified subjects. Such a design also allows separation of the effects of individual differences in operating skill from the effects of the independent variables.

Experimental Design (continued)

Sixteen Subjects and Two Independent Variables

Augmented Reality (AR) vs. no Augmented Reality (no AR)
Static harsh lighting (Harsh) vs. Ambient lighting (Amb)

Static harsh lighting is defined as a stationary, directed beam of light that will be cast upon the scene. It will create distinct shadows, thereby obscuring some of the features needed to complete the task.

Ambient lighting is defined as diffuse lighting that is currently used during training operations.

Experimental Design (continued)

Blocks of four subjects will be assigned to test conditions as follows:

Subject	Trial 1	Trial 2	Trial 3	Trial 4
A	AR / Harsh	no AR / Harsh	AR / Amb	no AR / Amb
B	no AR / Harsh	AR / Harsh	no AR / Amb	AR / Amb
C	AR / Amb	no AR / Amb	AR / Harsh	no AR / Harsh
D	no AR / Amb	AR / Amb	no AR / Harsh	AR / Harsh

Test plan

Testing will be conducted in the MRMDF in Building 9 at Johnson Space Center. Subjects will be given a summary of the study and will be re-familiarized with the controller interface. Subjects will be given 1 practice trial with no AR under ambient lighting. This combination will be most familiar to the subjects, as they typically operate the robotic arm under this condition. Subjects will complete the test according to the experimental design. Subjects will complete a questionnaire assessing their impressions of AR and the lighting conditions and their past experience with the robotic arm.

Dependent Variables (2)

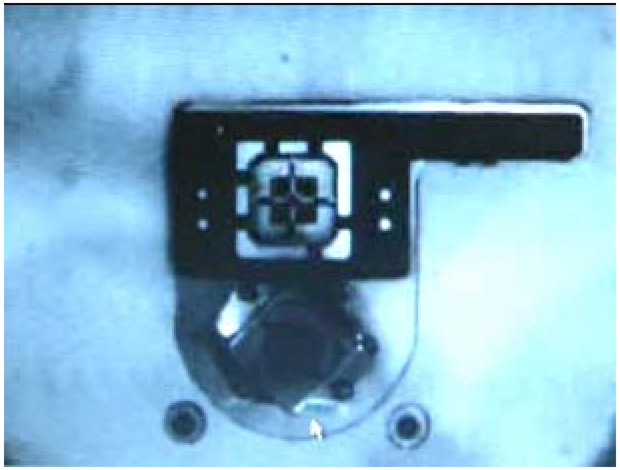
Time to completion
Accuracy

Task

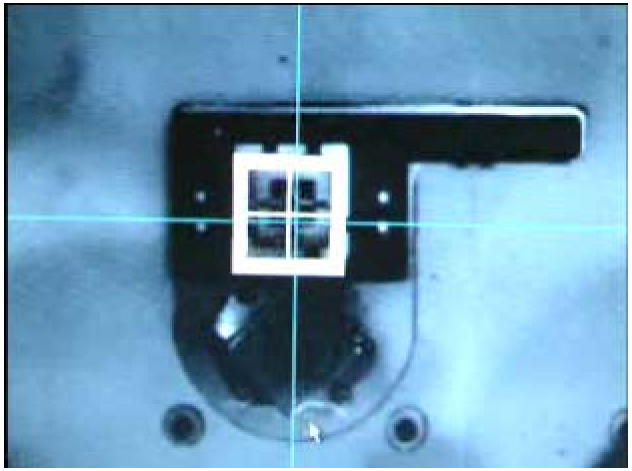
Subjects will use a robotic arm to mate its end effector with a payload grapple fixture. Operator will only be allowed the use of several cameras for viewing. Subjects will not be allowed to directly view the scene.

DMT aka SPDM maneuvers arm toward grapple fixture

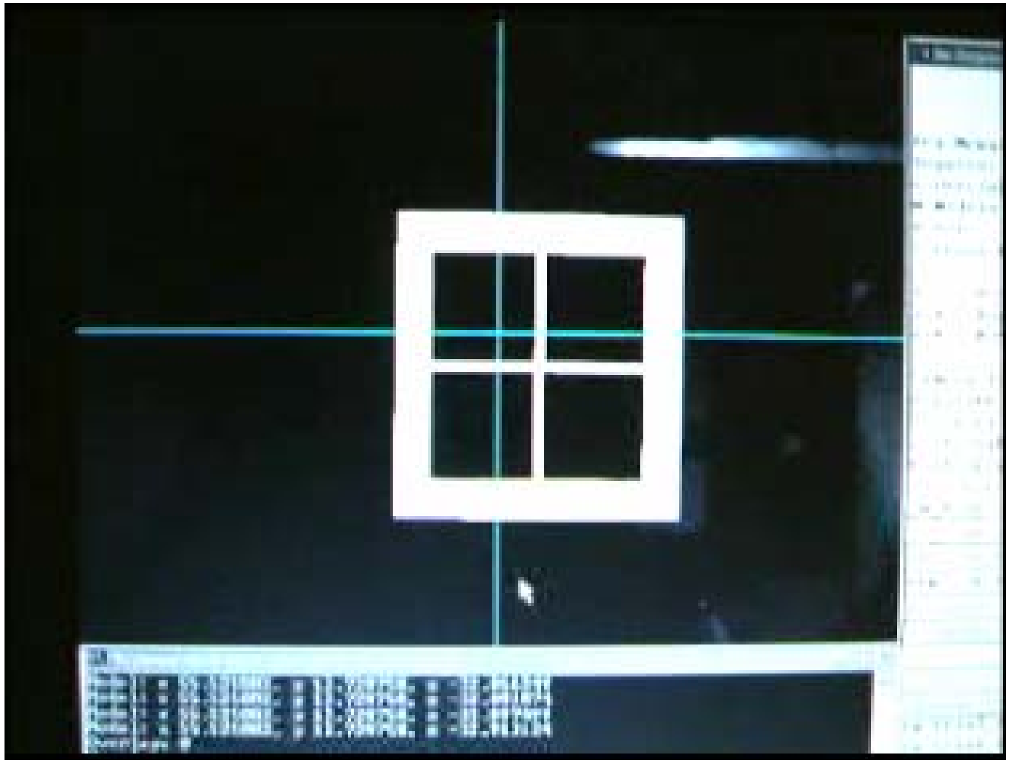
Grapple fixture view from DMT end-effector camera. Lap top computer with video and robotic positioning input is providing computer generator overlay augmentation of live video.



Grapple fixture alignment guide with no augmentation



Alignment guide with augmented reality overlay



DMT end-effector is at close range to grapple fixture, note the illumination quality has degraded, but augmentation of alignment guide is still useful.

Analysis

Time to task completion and accuracy data will be analyzed using analysis of variance. If significant differences between effects ($\alpha \leq 0.05$) are discovered, post-hoc T-tests will be performed to compare dependent measures.

Schedule

2003: Complete implementation of augmented reality system in the MRMDF.

2004: Pilot Testing, subject testing, analysis, and final report.

Conclusions/Products

If subjects testing results show significant improvement in human performance this will re-enforce recent findings [1,2] that augmentation of reality for space application does have a positive impact and that symbology is a factor.

The developed lap-top system is a highly portable and programmable system which will be used for future development of augmented reality symbology for other robotic devices, as well as, for other applications.

[1] Habitat 2004, "Utilization of the Space Vision System As An Augmented Reality System For Mission Operations"

[2] P.I. Workshop 2003, "Improving Human Task Performance with Luminance Images and Overlays"

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